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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
H05K 5/00

A1

(11) International Publication Number: WO 96/31105

(43) International Publication Date: 3 October 1996 (03.10.96)

(21) International Application Number: PCT/US96/04398

(22) International Filing Date: 29 March 1996 (29.03.96)

(30) Priority Data:
08/422,332 31 March 1995 (31.03.95) US

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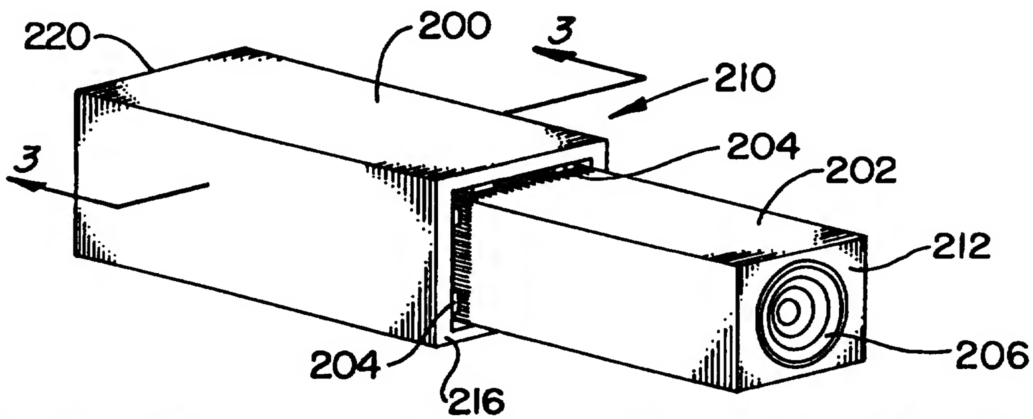
(81) Designated States: AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: LOW FREQUENCY AUDIO COUPLER AND METHOD OF COUPLING

(57) Abstract



A low frequency audio coupler (210) that produces a high sound pressure level in a listening environment. Both the front and back audio waves are used to optimize the produced sound. Three different embodiments all of which have a dual box structure. One embodiment includes an inner box (202) that may be pulled from an outer box (200) so as to tune the subwoofer. A second embodiment includes a dual box structure that directs front and back waves produced by a driver in opposite directions to create an omni-directional effect. The third embodiment includes a chute that wraps around a rear wall and side wall of the inner box so as to direct the produced back wave in the same direction as the produced front wave.

LOW FREQUENCY AUDIO COUPLER AND METHOD OF COUPLING

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to low frequency audio couplers, more commonly known to audiophiles as subwoofers. More particularly, the present invention relates to a highly efficient subwoofer which uses both the front and back waves produced by a driver to create an enveloping high energy, low frequency sound in a listening environment.

2. Description of the Related Art:

It was a dark and stormy night. A shot rang out. The maid screamed. Were the sounds live or a reproduction from a recording? Until recently, anyone could make that distinction. Even now, when asked to compare listening to the finest recording or the finest available audio system, and listening to a live performance, one audio expert indicated that the most significant difference is that the audio system could not reproduce the energy of the live performance.

Prior to the advent of digital technology for home application in the early 1980's; conventional signal processing and recording technologies, such as records and analog magnetic tapes of various sorts, simply were incapable of processing, recording or reproducing the energy associated with live performances. Typical conventional systems were designed and perfected to produce a flat response from 20 to 20,000 Hz, which is considered to be the audible range for average individuals.

The introduction of home applications for digital technology such as compact disks, digital audio tape, and digital compact cassette, and the more widespread use of DC coupled amplifiers, has changed the situation significantly. Such technology advances the drive for realism by providing a medium for capturing the energy lacking from prior technology for home use. If capabilities are utilized to the maximum, home systems can now generate electrical signals from recordings that contain information representing the energy of a live performance.

Unfortunately, loud speaker technology has not kept pace. Conventional loudspeakers are not able to transform the energy of the performance from electrical to acoustical form.

Of particular concern is the lower end of the frequency spectrum. Subwoofers have traditionally been designed as pictured in FIGURES 1A-1D. FIGURE 1A depicts a closed box speaker including simply a driver 102 mounted on a wall of box 100. Although quite often used in audio speaker design, the closed box is inefficient as more electrical power is needed for the driver than with a ported speaker design. Typically, closed box subwoofers have been designed to generate sound down to about 20 Hz.

FIGURE 1B illustrates a Helmholtz resonator, which is more efficient than is the closed box, but is still unable to produce a sound pressure level capable of filling large expanses or of producing an energy as experienced at a live performance. This type of prior art subwoofer includes a driver 106 mounted in a box 108. A port is provided in the side of box 108 in which driver

106 is mounted. Helmholtz resonator subwoofers have not been designed to operate below 20 Hz.

FIGURE 1C portrays a tuned port speaker, which permits more precise tuning but does not have the ability to generate the necessary sound pressure level for large expanses Such a speaker can be "tuned" by varying the length of tube 114. The speaker includes box 110 having a driver 112 mounted therein. Tube 114 opens from the interior of the box 110 to the listening environment through the same face of box 110 in which driver 112 is mounted. Again, this design has not typically operated below 20 Hz.

FIGURE 1D depicts a labyrinth type subwoofer. The labyrinth subwoofer is designed to produce the lowest audio frequencies of traditional speakers. The labyrinth produces down to almost 16 Hz, but in order to do this, the labyrinth is massive in size. The labyrinth operates on the principle of absorbing as much back wave energy as possible, rather than using this energy to recreate the original soundstage.

U.S. Patent 4,567,959 to Prophit teaches a tuned port type subwoofer. This speaker does not even have the ability to drop down to 20 Hz. Rather, Prophit discloses that "[t]ypical music is such that the lowest common note that should be reproduced, is low F (43.65 Hertz)". Column 4, lines 26-28.

Figure 2 of Kowalik et al., U.S. Patent 3,394,773, depicts a three-dimensional exploded view of a two-piece loudspeaker chamber having a telescopic relation. This device only relies on the front waves of the audio speaker for the production of sound, and the speaker fails to realize the

importance of the back wave of an audio signal in recreating the energy from a live performance.

U.S. Patent 4,298,087 to Launay is directed to a unidirectional speaker, quite distinct from a nondirectional subwoofer. This patent describes a box, within a box structure, the internal boxes being relied upon to enhance damping factor characteristics. It is a goal of this speaker to provide a substantially closed box design with tight control.

Two patents assigned to the Bose Corporation, U.S. Patents 4,549,631 to Amar G. Bose and 5,025,885 to Froeschle both teach loudspeakers that rely on both the front and back audio waves. Both teach dividing a larger box with a baffle and having a woofer/driver mounted on the baffle. The front and back waves pass through ports prior to exiting the enclosure.

None of these speakers solve the problem of recreating the energy and realism of a live performance. None of these prior subwoofers suggest that by producing sounds that cannot be heard by the human ear, the energy and vitality of a live performance.

SUMMARY OF THE INVENTION

The present invention overcomes the problems of prior subwoofers by providing a subwoofer more capable of producing the energy of a live performance than was previously possible. The present inventor has determined that an important aspect of being able to reproduce such energy is reproducing the sub-audio section of the audio spectrum, from above 0 to below 20 Hz, as well as producing frequencies in the audible range from 20

to 200 Hz. The sounds produced by the present invention have the vitality and power associated with a live performance.

The present invention uses both the back waves and the front waves to fill a listening environment with sound and energy. Variations in the volume through which the back wave of the present invention travels, causes changes in impedance experienced by the sound waves resulting in the present invention having a low Q compared to other subwoofers.

The present invention is a low frequency audio transfer unit, that includes an enclosure. That is, the enclosure is sized so that the lowest modal resonant frequency of the enclosure is above the operating frequency of the audio transfer unit.

In the present invention an input electrical signal is converted into an audio signal by means for producing an acoustic distribution in a range of from above 0 Hz to below 200 Hz from said electrical signal. The acoustic distribution is coupled to the listening environment by means for coupling a front audio wave and a back audio wave of the distribution to the listening environment, where the coupling means includes means for enhancing a section of the acoustic distribution from above 0 Hz to below 20 Hz. The undersized enclosure helps achieve the sub-audio frequencies by preventing any resonance points in the operating frequency range of the invention. The sub-audio frequencies are reproduced without exceeding acceptable sound pressure levels above 20 Hz.

The present invention is exemplified by three embodiments, all of which employ both the front and back waves emanating from a driver. Further, the low Q and the ability to produce

signals in the sub-audio region of the audio spectrum enables the present invention to enter a world of sound recreation never before attempted by prior subwoofers.

The first embodiment of the present invention is directed toward a low frequency audio transfer unit, structured as a box within a box. The driver is mounted facing outward from the inner of the two boxes. Back waves travel towards the rear of the inner box and are ported to the outer box through an opening in the rear wall of the inner box. This opening is desirably triangular, but the shape can be varied. Once exiting the inner box, the back waves follow a channel formed between the inner and outer boxes and return toward the front of the box. The returning back waves exit from the channel that surrounds the inner box, thus producing an increased sound pressure level.

The second embodiment of the present invention, while not causing the front and back waves to exit in the same direction, does have the front and back waves exiting in-phase. A driver unit is disposed in an inner box at one end thereof. Front waves are directed to the listening environment via a channel that runs from the end where the speaker is positioned to the opposite end of the inner box. The back waves produced by the driver travel through the inner box to an opening in a corner diagonally disposed from the driver. The opening connects to another channel through which the back waves travel back toward the end of the speaker at which the driver is disposed. Thus, although the front and back waves exit from the enclosure in opposite directions, the waves are in-phase, thus increasing the sound pressure level coming from the audio transfer unit and filling the

listening environment with the energy of the original performance. The sound is uniform throughout the listening environment.

The third embodiment of the low frequency audio transfer unit couples the front wave directly to the listening environment. The back waves travel around an interior baffle and exit the interior chamber though a passage that wraps around the outside of the inner box. The back wave is wrapped around the inner box so that it exits from the enclosure in the same direction as the front wave, and in-phase with the front wave. Thus, the back waves travels through different volume sections of the enclosure so as to provide the subwoofer with a low Q and recreate the energy of a live performance.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and characteristics of the present invention, as well as methods of operation and functions of the related elements, will become apparent upon consideration of the following description and the appended claims with reference to the drawings, all of which form a part of this specification, of which:

FIGURES 1A - 1D schematically illustrate basic designs of prior art subwoofers;

FIGURE 2A is a perspective view of a first embodiment of the present invention in an expanded position;

FIGURE 2B is a perspective view of the first embodiment of the present invention with the inner and outer boxes of the embodiment separated;

FIGURE 3A is a view of the rear wall of the inner box showing a triangular hole coupling the

back wave to the outer box taken along the 3-3 line of FIGURE 2A;

FIGURE 3B is a view of the rear wall of the inner box showing circular hole coupling the back wave to the outer box taken along the 3-3 line of FIGURE 2A;

FIGURE 4A is a schematic sectional view of a second embodiment of the present invention;

FIGURE 4B is a perspective view of the second embodiment of the present invention;

FIGURE 5A is a schematic sectional view of a third embodiment of the present invention; and

FIGURE 5B depicts a perspective view of the third embodiment.

DETAILED DESCRIPTION OF THE PRESENTLY PREFERRED EXEMPLARY EMBODIMENTS

The embodiments described in combination with the present invention are preferably made from wood, although other materials, such as plastics or metals, are possible. The present invention provides a low frequency audio transfer unit that receives an electrical signal from an exterior amplifier. The signal is transformed into an acoustic distribution, by a system including a driver which produces a front and a back wave, both of which are directed to a listening environment. The low frequency audio transfer unit according to the present invention enhances the section of the acoustic distribution in the sub-audio, that is from 0 to 20 Hz by relying on the back and front wave. Besides providing sub-audio signals, the present invention also produces audio signals from 20 Hz to below 200 Hz in order to recreate the entire

distribution produced by the original live performance between above 0 Hz to below 200 Hz.

Embodiment 1

FIGURES 2A, 2B, 3A, and 3B illustrate views of the first embodiment of the present invention. A low frequency audio coupler 210 includes inner box 202 and outer box 200. Outer box 200 is large enough so that inner box 202 can be slid within interior space 214 of outer box 200 so that surface 212 of inner box 202 is flush with surface 216 of outer box 200. Inner box 202 is spaced from the interior walls of box 200 by runners 204. Runners 204 are between .25 and 1.0 inches in height, thereby maintaining that much of a gap between inner box 202 and outer box 200 on all sides.

Driver 206 is mounted on face 212 of inner box 202. Sound waves produced by driver 206 have front and back wave components. The front wave components exit directly to the listening environment while the back waves components travel towards rear face 218 of inner box 202. The back waves exit inner box 202 via triangular opening 208. FIGURES 3A and 3B depict sectional views showing rear face 218 of inner box 202. Opening 208 may be triangular or circular. Other shapes are also possible, but the triangular shape is presently preferred. The back waves exit inner box 202 to the gap formed between inner box 202 and outer box 200. As described above, the gap is maintained at a desired spacing through use of spacers 204. The back waves then bounce off rear wall 220 of outer box 200 and travel towards front face 216. The back waves exit on all four sides of inner box 202 through the gap formed by spacers 204.

Dimensions of the subwoofer according to this embodiment of the present invention are determined by the size of the driver being used and the thickness of the material being used for the enclosure. The length of inner box 202 is about 2.2 times the diameter of the driver. The width and height of inner chamber 202 is about 1.1 time the driver diameter. Triangular hole 208 has sides with a length of about 0.7044 times the driver diameter. If a circular hole should be used in place of triangular hole 208, then the circular hole should have a diameter of about 0.261 times the driver diameter. The opening, whether it be triangular or circular, has a constant volume. Lastly, the air-gap between inner box 202 and outer box 200 is approximated by the following equation:

$$\frac{(0.1375 \cdot \text{driver diameter}^2)}{(4.4 \cdot \text{driver diameter}) + (2 \cdot \text{material thickness})}.$$

All other dimensions are logically deduced from these dimensions.

This subwoofer provides full 0-200 Hz range but also produces a strong subaudio signal between 0 and 20 Hz. The undersizing of the enclosure allows for a strong signal between 0 and 20 Hz while preventing excessive energy from being produced between 20 and 200 Hz. Maximum air movement is produced from 0 to 20 Hz. By placing the hole in the interior cabinet as far from the driver as possible, enhanced subaudio energy can be produced.

<u>Embodiment 2</u>

FIGURES 4A and 4B are views of a second embodiment of the present invention, wherein front waves and back waves travel distinct paths and are output in opposite directions, thereby producing a

non-directional effect as the front and rear waves are in-phase.

In the second embodiment, audio coupler 422 is again essentially a box within a box. The interior box includes side walls 424 and 426, lower wall 416 and upper wall 414. Driver 410 is mounted so as to face downward in a hole formed in wall 416 near side wall 426. Driver 410 points into channel 408, through which front waves 400 travel into the listening environment.

The second box includes side walls 424 and 426, lower wall 418 and upper wall 412. Thus side walls 424 and 426 are shared by the inner and outer boxes. Channel 408 through which the front waves travel is formed by lower wall 416 of the inner box and lower wall 418 of the outer box, while channel 404 is formed by upper wall 414 of the inner box and upper wall 412 of the outer box.

Front wave 400 produced by driver 410 travels through lower channel 408 and exits through a port formed in side wall 424. Back wave 402 travels across interior space 420 and enters upper channel 404 through opening 406 formed in wall 414 diagonally opposite driver 410. Having passed through opening 406, back wave 402 travels upper channel 404 and exits from the audio coupler via a port formed in side wall 426. Back wave 402 exits audio coupler 422 in an direction opposite to the exit direction of front wave 400.

Due to the different directions traveled by front wave 400 and back wave 402 and the fact that the two waves exit in-phase, audio coupler 422 has the effect of providing omni-directional sound. Further, the audio coupler 422 produces an increase in sound pressure level experienced in the listening

environment due to the differing output directions for the front and back waves.

As in the first embodiment, the dimensions of the subwoofer described above are related to the size/diameter of the driver being used. If the diameter of the driver is represented by DD, then each channel has a length of about 2.4 times DD. Interior space 420 has a height of about 0.75 times DD. Audio coupler 422 has a width W shown in FIGURE 4B of approximately 1.1 times DD. Finally, opening 406 has a width of approximately 0.31 times DD and a length of approximately 0.6875 times DD.

This subwoofer provides full 0-200 Hz range but also produces a strong subaudio signal between 0 and 20 Hz. The undersizing of the enclosure allows for a strong signal between 0 and 20 Hz while preventing excessive energy from being produced between 20 and 200 Hz. Maximum air movement is produced from 0 to 20 Hz. By placing the opening in the interior cabinet as far from the driver as possible, enhanced subaudio energy can be produced.

Embodiment 3

The third embodiment of the present invention also produces a superb sound having an enhanced section of the audio spectrum between 0 Hz and 200 Hz. The low frequency audio coupler is shown in FIGURES 5A and 5B.

In this embodiment of the present invention, coupler 518 is essentially a box on top of a box. The inner box, as depicted in FIGURE 5A, is formed of front wall 522, in which driver 500 is mounted, rear wall 516, lower wall 514 and upper wall 520. Of course, as shown in FIGURE 5B, the inner box has side walls 524. The outer box

resembles a chute in configuration as it wraps around a portion of the outer periphery of the inner box. Chute 506 runs adjacent to rear wall 516 and upper wall 520 and is defined by upper wall 508 and rear wall 528. Further, the lowermost section of chute 506 is a protrusion from lower wall 514. Chute 506 has side walls 526. Preferably, chute 506 has a width significantly less than the width of audio coupler 518 as is illustrated in FIGURE 5B.

Low frequency audio coupler 518 includes driver 500 that converts electrical signals into low frequency (between 0 and 250 Hz) audio signals. Driver 500 produces both front wave 502 and back wave 504. Front wave 502 exits audio coupler 518 directly to the listening environment. However, back wave 504 follows a circuitous path before it emerges into the listening environment. That is, back wave 504 travels around diagonal partition 510 and then passes through opening 512 formed in the corner of rear wall 516. Opening 512 is preferably formed near the position where lower wall 514 and partition 510 are joined. Back wave 504 passes through opening 512 and enters chute 506. After travelling through chute 506, back wave 504 exits from chute 506 travelling in the same direction as front wave 502. Chute 506 has its opening flush with front wall 522.

The size of this embodiment is dependent upon the diameter of the driver of the present invention. The length of low frequency audio transfer unit 518 is approximately equal to 2.2 times the driver diameter. The volume of the inner box that is divided by baffle 510 is calculated as follows:

$$[(\text{length})^3 - 2\cdot(\text{driver diameter}) + (\text{driver diameter})_2]$$
$$\text{times } (.1610739) = \text{volume} \pm 10\%.$$

Once these figures are known, the size of opening 512 is calculated as follows:

Perimeter of Hole = 2 · (driver diameter)

Chute 506 has a height approximately equal to one tenth of the length of the enclosure.

This subwoofer provides full 0-200 Hz range but also produces a strong subaudio signal between 0 and 20 Hz. The undersizing of the enclosure allows for a strong signal between 0 and 20 Hz while preventing excessive energy from being produced between 20 and 200 Hz. Maximum air movement is produced from 0 to 20 Hz. By placing the opening in the interior cabinet as far from the driver as possible, enhanced subaudio energy can be produced.

The present invention has been described in connection with what is presently considered to be the most practical and preferred embodiments. However, it is to be understood that the invention is not to be limited to the disclosed embodiments, but rather is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims.

WHAT IS CLAIMED IS:

1. A low frequency audio transfer unit, comprising:

an enclosure sized so that a lowest modal resonance frequency is above an operating frequency of said low frequency audio transfer unit;

means for accepting an electrical signal having frequency components from above 0 to Hz to below 200 Hz;

means for producing an acoustic distribution in a range of from above 0 Hz to below 200 Hz generated from said electrical signal; and

means for coupling a front audio wave and a back audio wave of said distribution to a listening environment, said coupling means including means for enhancing a section of said distribution from above 0 Hz to below 20 Hz;

wherein said low frequency audio transfer unit produces maximum air movement within said section of said distribution.

2. A low frequency audio transfer unit as claimed in claim 1, wherein said producing means is a low frequency audio driver.

3. A low frequency audio transfer unit as claimed in claim 2, wherein said producing means is disposed on an outside wall of said enclosure so as to have said front wave directly coupled to a listening environment.

4. A low frequency audio transfer unit as claimed in claim 2, wherein said coupling means includes first and second channels through which said front and back waves travel, respectively.

5. A low frequency audio transfer unit as claimed in claim 4, wherein said enclosure is disposed between said first and second channels.

6. A low frequency audio transfer unit as claimed in claim 3, wherein said enclosure includes an inner and an outer box, said inner box being slidably disposed within said outer box.

7. A low frequency audio transfer unit as claimed in claim 6, wherein said coupling means includes an opening formed in a back wall of said inner box.

8. A low frequency audio transfer unit as claimed in claim 7, wherein said opening is triangular.

9. A low frequency audio transfer unit as claimed in claim 7, wherein said opening is circular.

10. A low frequency audio transfer unit as claimed in claim 7, wherein said coupling means further includes a space between the inner and outer boxes, said back wave travelling through said space.

11. A low frequency audio transfer unit as claimed in claim 3, wherein said enclosure includes a baffle extending from a bottom rear corner of said enclosure.

12. A low frequency audio transfer unit as claimed in claim 11, wherein said coupling means includes an opening formed in a rear wall of said enclosure above said baffle.

13. A low frequency audio transfer unit as claimed in claim 12, wherein said coupling means further includes a chute extending on an exterior side of said rear wall and an upper wall of said enclosure.

14. A low frequency audio transfer unit as claimed in claim 13, wherein said chute has a width less than that of said enclosure.

15. A low frequency audio transfer unit as claimed in claim 12, wherein said opening has a perimeter equal to approximately twice the driver diameter.

16. A low frequency audio coupler that produces audio signals between 0 and 200 Hz, comprising:

an enclosure having a front wall, rear wall and side walls;

means for producing audio signals from input electrical signals, said producing means producing both a front audio wave and a back audio wave, said producing means being mounted in said enclosure so as allow said front audio wave to exit directly to a listening environment and to allow said back audio wave to travel across an interior space of said enclosure;

means for directing said back wave, said directing means including a passage formed so as to allow said back wave to travel along an outer surface of at least said rear wall and one of said side walls of said enclosure; and

means for coupling said back wave to said directing means after said back wave has travelled across said interior space of said enclosure.

17. A low frequency audio coupler as claimed in claim 16, wherein said producing means is a low frequency audio driver mounted in said front wall of said enclosure.

18. A low frequency audio coupler as claimed in claim 17, wherein said coupling means includes a triangular opening formed in said rear wall of said enclosure.

19. A low frequency audio coupler as claimed in claim 18, wherein said directing means is a second enclosure formed so as to enclose said side walls and said rear wall of said enclosure.

20. A low frequency audio coupler as claimed in claim 19, wherein said enclosure is slidable along said second enclosure in the direction that said front wall of said enclosure faces, whereby said enclosure may be disposed at any position along said direction relative to said second enclosure.

21. A low frequency audio coupler as claimed in claim 20, further comprising runners disposed between interior walls of said second enclosure and an outer surface of said side walls of said enclosure that separate said enclosure from said second enclosure.

22. A low frequency audio coupler as claimed in claim 17, wherein said directing means is

a chute formed on said rear wall and one of said side walls of said enclosure.

23. A low frequency audio coupler as claimed in claim 22, wherein said coupling means includes an opening formed in said rear wall proximate an end of said chute.

24. A low frequency audio coupler as claimed in claim 23, wherein said low frequency audio coupler further comprises a diagonal partition that extends into an interior space of said enclosure from a position proximate said opening and between said opening and said driver.

25. A low frequency audio coupler as claimed in claim 22, wherein said chute has a width less than a width of said enclosure.

26. A low frequency audio coupler for producing audio energy in the range of from 0 to 200 Hz, comprising:

an inner box having a plurality of side walls and first and second end walls;

means for producing sound disposed in a first opening formed in one of said side walls of said inner box near said first end wall, said producing means producing a front audio wave and a back audio wave;

a first passage disposed adjacent an exterior surface of said one side wall and having a closed end adjacent said first end wall and an open end adjacent said second end wall, said producing means mounted so as to direct said front wave into said first passage adjacent said closed end;

a second passage disposed adjacent an exterior surface of another of said side walls and having a closed end adjacent said second end wall and an open end adjacent said first end wall; and

means for coupling said back wave into said second passage adjacent said closed end of said second passage.

27. A low frequency audio coupler as claimed in claim 26, wherein said producing means is a low frequency audio driver.

28. A low frequency audio coupler as claimed in claim 27, wherein said coupling means is an opening formed in said another wall proximate said second end wall.

29. A method for producing acoustic energy in the range of from 0 to 200 Hz from an input electrical signal, said method comprising the steps of:

producing acoustic energy from the electrical signal input, said acoustic energy having a front acoustic wave and a back acoustic wave;

enhancing the acoustic energy of said front acoustic wave and said rear acoustic wave having frequencies from above 0 Hz to below 20 Hz, said enhancing step including maximizing airflow to a listening environment from 0 to 20 Hz;

coupling said front acoustic wave and said back acoustic wave to the listening environment.

30. A method for producing audio energy as claimed in claim 29, wherein said enhancing step includes directing said rear acoustic wave through

different sections of an enclosure of said low frequency audio transfer unit.

33. A method for producing audio energy as claimed in claim 30, wherein said enhancing step includes directing both said front and said rear acoustic wave through different sections of an enclosure of said low frequency audio transfer unit.

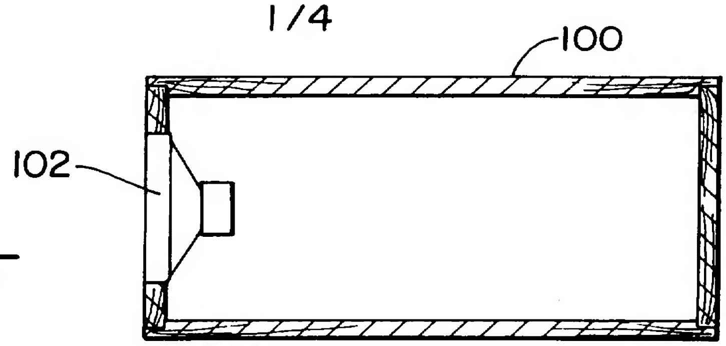


FIG. 1A
(PRIOR ART)

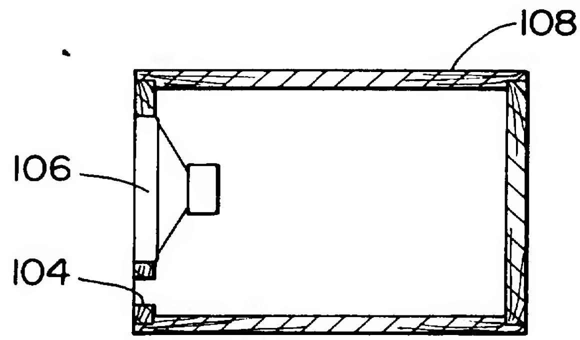


FIG. 1B
(PRIOR ART)

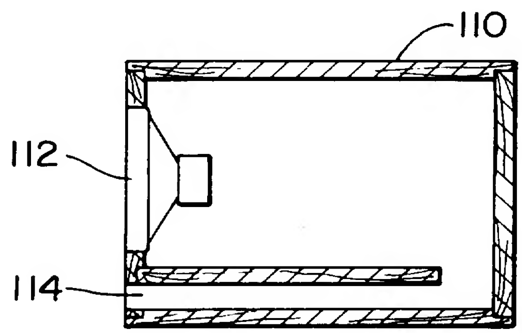


FIG. 1C
(PRIOR ART)

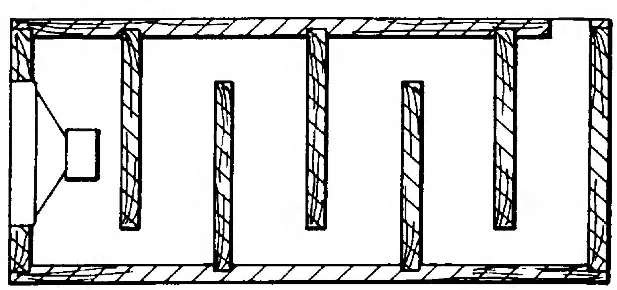


FIG. 1D
(PRIOR ART)

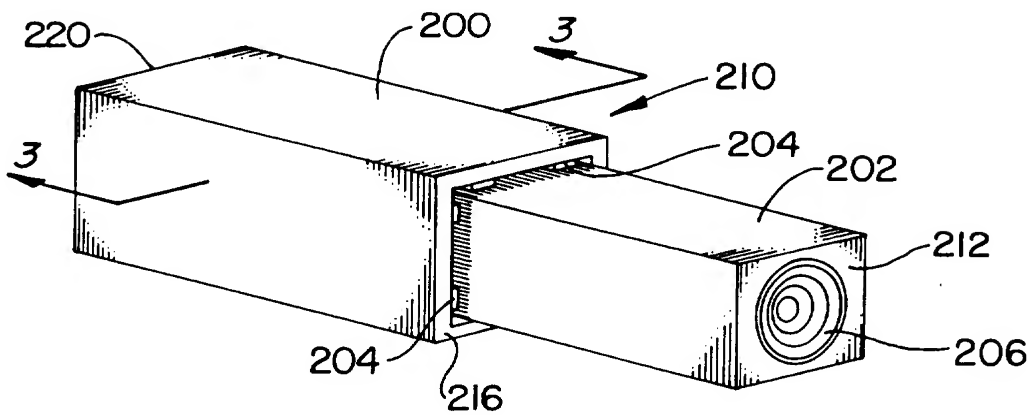


FIG. 2A

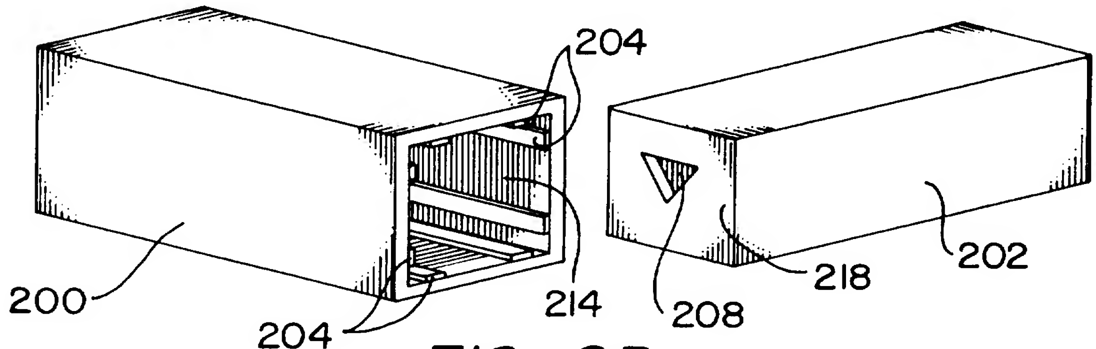
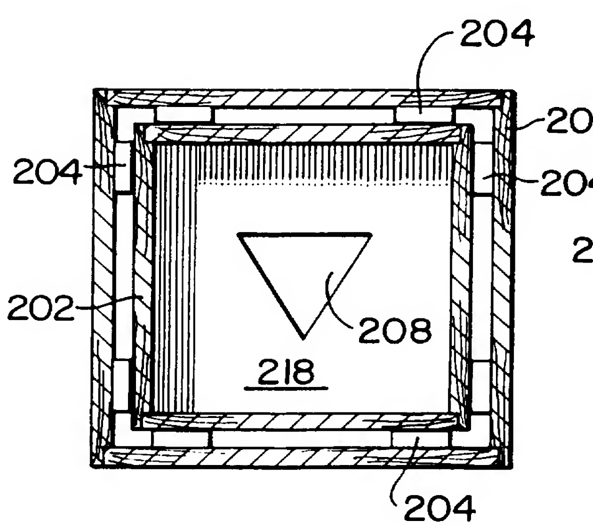


FIG. 2B



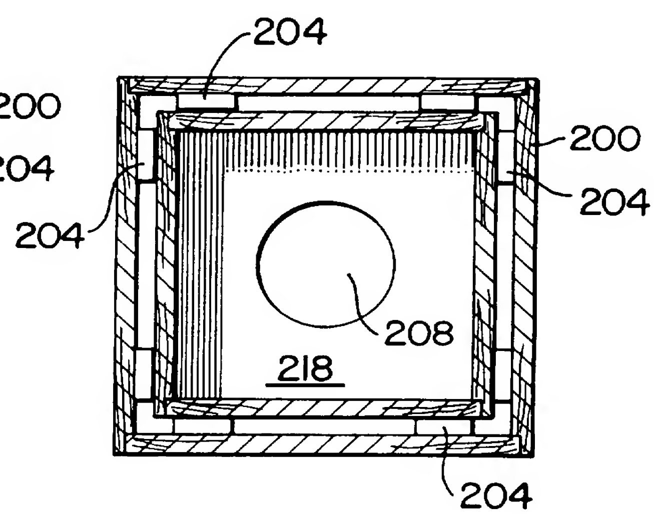
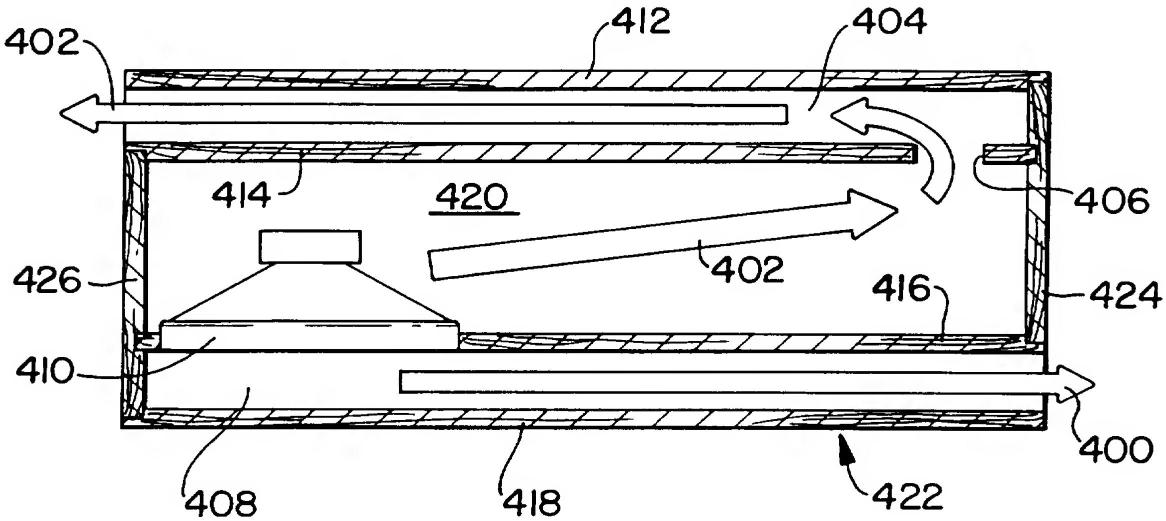


FIG. 3A

FIG. 3B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422

FIG. 4A

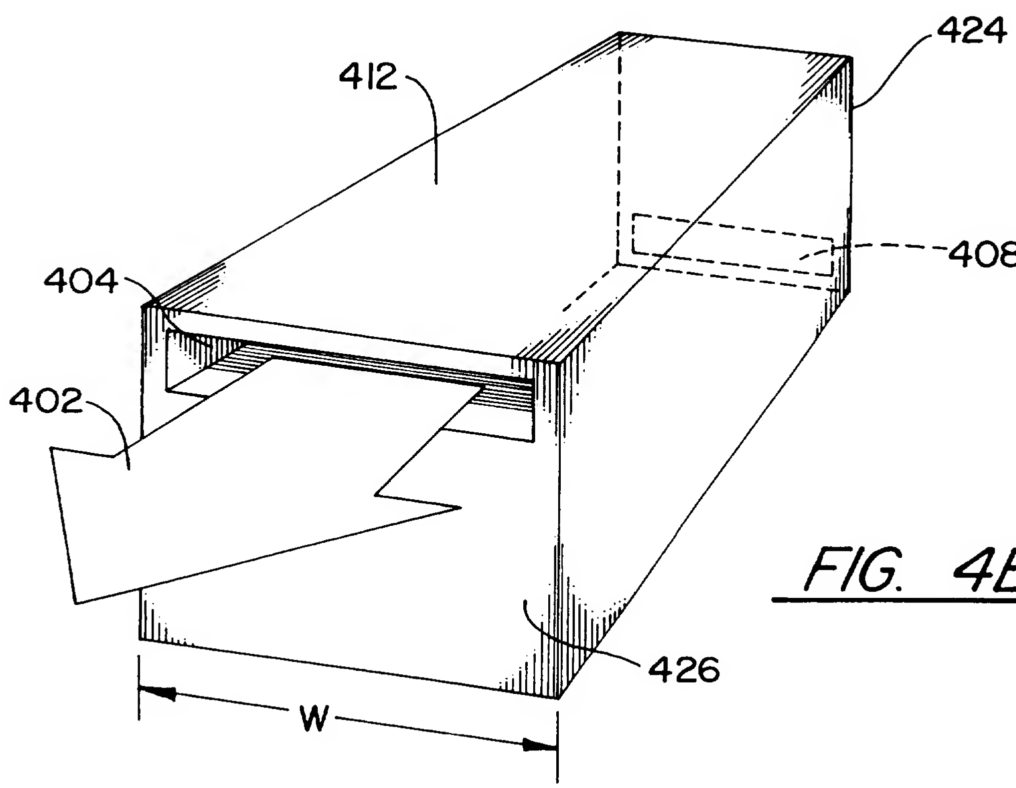
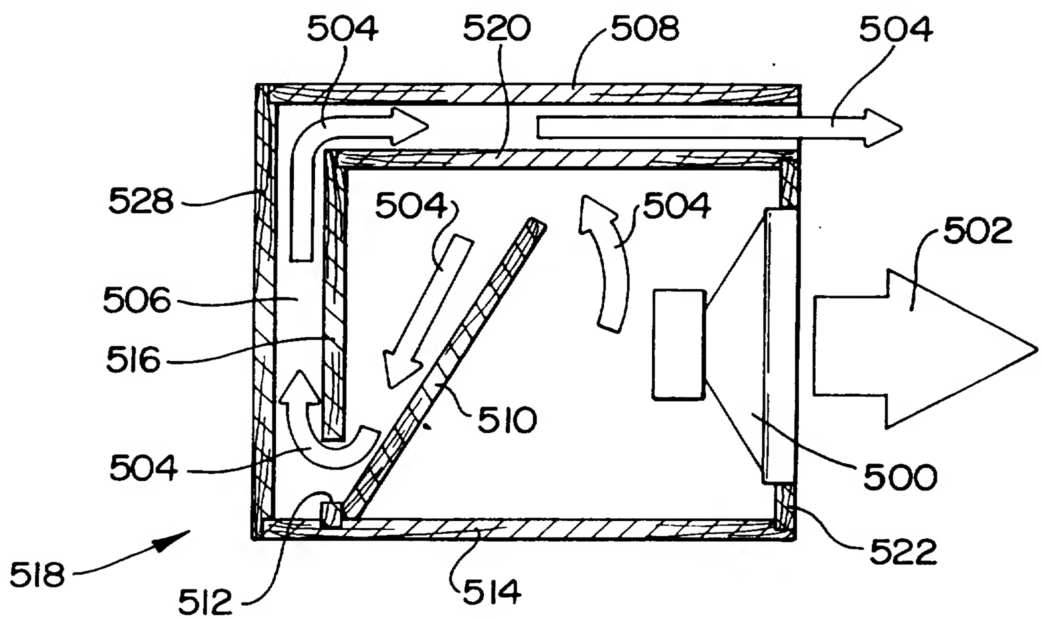

424
412
408
404
402
426
W

FIG. 4B


504
520
508
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528
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504
502
506
516
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504
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522
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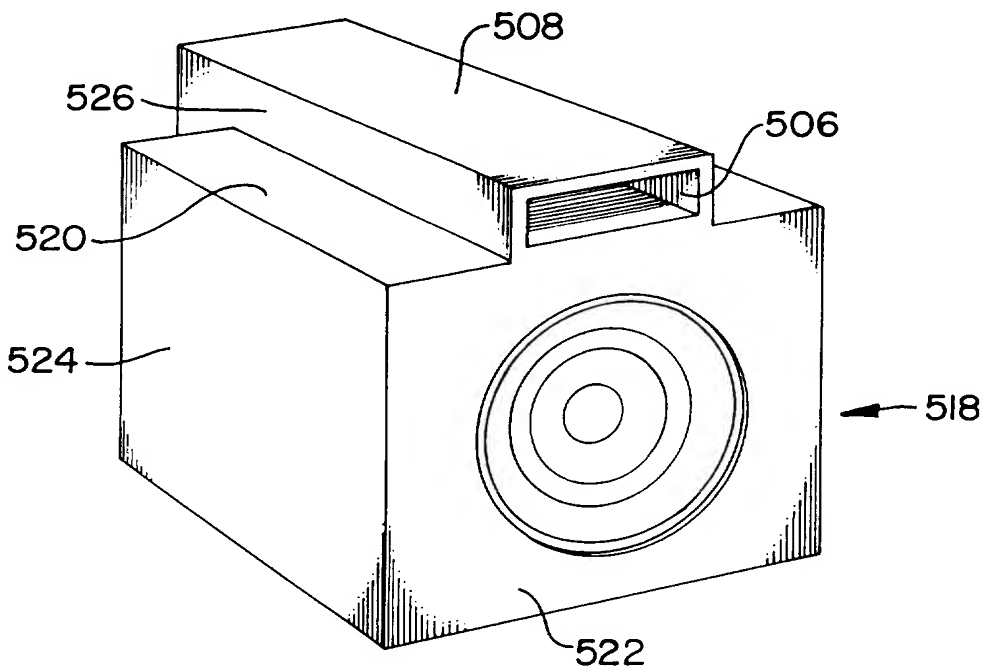
512
514

FIG. 5A


508
526
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520
524
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522

FIG. 5B

INTERNATIONAL SEARCH REPORT	International application No. PCT/US96/04398

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H05K 5/00
US CL :181/152, 156, 160, 199 ; 381/156, 159
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 181/152, 156, 160, 199 ; 381/156, 159

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,189,706 (SAEKI) 23 FEBRUARY 1993, see Figs. 1, 2, and 4, column 2, line 52 to column 3, line 3, column 3, lines 31-38.	1-7, 9, 10, 16, 17, 22, 23, 25-31
X	US, A, 5,111,905 (RODGERS) 05 DECEMBER 1992, Fig. 2, column 4, line 52 to column 6, line 38.	1-3, 11, 16, 17, 29, 30, and 31
X	US, A, 5,197,103 (HAYAKAWA) 23 MARCH 1993, see Figs 1b.	1-5, 11-14, 16, 17, 22, 23, 25-31
X	US, A, 3,945,461 (ROBINSON) 23 MARCH 1976, see Fig. 1, column 2, lines 31-56.	1-7, 9, 16, 17, 29-31

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 AUGUST 1996	14 AUG 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer for KHANH DANG Telephone No. (703) 308-0211

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